FINAL REPORT
AUGUST 1996

REPORT NO. 93-17

MILITARY ISO-CONTAINER TEMPERATURE EVALUATION FOR U.S. ARMY NATICK RESEARCH, DEVELOPMENT AND ENGINEERING CENTER (NRDEC)

Prepared for:
Commander
U.S. Army Natick Research Development
and Engineering Center
ATTN: SATNC-USOS
Natick, MA 01760-5017

Distribution Unlimited

U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL
Savanna, Illinois

VALIDATION ENGINEERING DIVISION
SAVANNA, ILLINOIS 61074-9639

AVAILABILITY NOTICE

A copy of this report will be furnished each attendee on automatic distribution. Additional copies or authority for reprinting may be obtained by written request from Director, U.S. Army Defense Ammunition Center and School, ATTN: SIOAC-DEV, Savanna, IL 61074-9639.

DISTRIBUTION INSTRUCTIONS

Destroy this report when no longer needed. Do not return.

***

Citation of trade names in this report does not constitute an official endorsement.

***

The information contained herein will not be used for advertising purposes.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT UNLIMITED
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) 93-17	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Defense Ammunition Center and School 6b. OFFICE SYMBOL *(if applicable)* SIOAC-DEV	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS *(City, State, and ZIP Code)* ATTN: SIOAC-DEV Savanna, IL 61074-9639	7b. ADDRESS *(City, State, and ZIP Code)*
8a. NAME OF FUNDING / SPONSORING ORGANIZATION U.S. Army Natick Research, Development and Engineering Center 8b. OFFICE SYMBOL *(if applicable)* SATNC-USOS	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS *(City, State, and ZIP Code)* ATTN: SATNC-USOS Natick, MA 01760-5017	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*

Military ISO-Container Temperature Evaluation for U.S. Army Natick Research, Development and Engineering Center (NRDEC)

12. PERSONAL AUTHOR(S)

Quinn D. Hartman

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT
Final	FROM ——— TO ———	1996 August	

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

The U.S. Army Defense Ammunition Center and School (USADACS), Validation Engineering Division (SIOAC-DEV), was tasked by U.S. Army Natick Research, Development and Engineering Center (NRDEC) to evaluate the benefits of various solar radiation protection methods for International Organization for Standardization (ISO) shipping containers. Protection methods tested consisted of the following: ceramic coatings from Florida Institute of Technology (FIT), NRDEC container cover; NRDEC double-thickness tarpaulin; a container cover from Fit's-Right Canvas and Supply, a Division of Worldwide Container Services, Inc.; enamel white paint; and tan paint. A SeaVent container from Sea Containers Services Ltd. was also tested against these protection methods to assess potential benefits of a container with vents. Results from the evaluation indicated that the NRDEC double-thickness tarpaulin, NRDEC container cover, and the enamel white paint provided the best overall protection against temperature elevation caused by exposure to solar radiation. Results from the evaluation also indicated that the SeaVent container was within approximately 10 degrees Fahrenheit of the best protection methods.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT XX UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL JEROME H. KROHN	22b. TELEPHONE *(Include Area Code)* 815-273-8929 — 22c. OFFICE SYMBOL SIOAC-DEV

DD Form 1473, Jun 86 — *Previous editions are obsolete* — SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL
VALIDATION ENGINEERING DIVISION
SAVANNA, IL 61074-9639

REPORT NO. 93-17

MILITARY ISO-CONTAINER TEMPERATURE EVALUATION FOR U. S. ARMY NATICK RESEARCH, DEVELOPMENT AND ENGINEERING CENTER (NRDEC)

TABLE OF CONTENTS

PART 1

INTRODUCTION

A. BACKGROUND. The U.S. Army Defense Ammunition Center and School (USADACS), Validation Engineering Division (SIOAC-DEV), was tasked by U. S. Army Natick Research, Development and Engineering Center (NRDEC) to evaluate the benefits of various solar radiation protection methods for ISO shipping containers. Testing was conducted during the summer months of 1992, 1993, 1994 and 1995 at USADACS, Savanna, IL. Protection methods tested consisted of the following: ceramic coatings from Florida Institute of Technology (FIT), NRDEC container cover; NRDEC double-thickness tarpaulin; a container cover from Fit's-Right Canvas and Supply, a Division of Worldwide Container Services, Inc.; enamel white paint; and tan paint. A SeaVent container from Sea Containers Services Ltd. was also tested against these protection methods to assess potential benefits of a container with vents.

B. AUTHORITY. The test was accomplished IAW mission responsibilities delegated by U.S. Army Armament Munitions and Chemical Command (AMCCOM), Rock Island, IL. Reference is made to the following:

1. Change 4, 4 October 1974, to AR740-1, 23 April 1973, Storage and Supply Activity Operation.

2. AMCCOM-R, 10-17, Mission and Major Functions of USADACS, 13 January 1986.

C. OBJECTIVE. The objective of the environmental monitoring was to determine which methods provided the best protection against temperature elevation caused by exposure to solar radiation.

D. CONCLUSION. Results from the evaluation indicated that the NRDEC double-thickness tarpaulin, NRDEC container cover, and the enamel white paint provided the best overall protection against temperature elevation caused by exposure to solar radiation. Results from the evaluation also indicated that the SeaVent container was within approximatly 10 degrees Fahrenheit of the best protection methods.

PART 2

SUMMER MONTHS OF 1992, 1993, 1994, AND 1995

ATTENDEES

Quinn D. Hartman General Engineer DSN 585-8992 815-273-8992	Director U.S. Army Defense Ammunition Center and School ATTN: SIOAC-DEV Savanna, IL 61074-9639
William R. Meyer General Engineer DSN 585-8090 815-273-8090	Director U.S. Army Defense Ammunition Center and School ATTN: SIOAC-DEV Savanna, IL 61074-9639
Bradley J. Haas Mechanical Engineer DSN 585-8336 815-273-8336	Director U.S. Army Defense Ammunition Center and School ATTN: SIOAC-DEV Savanna, IL 61074-9639
David V. Valant Electronics Technician DSN 585-8988 815-273-8988	Director U.S. Army Defense Ammunition Center and School ATTN: SIOAC-DEV Savanna, IL 61074-9639

PART 3

TEST SETUP

Test data collection was performed using a Climatronics Corporation weather station equipped to monitor up to 32 external thermocouple sensors. Thermocouple sensors were placed in identical positions on the tested containers to minimize the effects that varying probe position could have on the test data. The test points for each container were exterior top of the container, interior top of the container, six inches below the top of the container, top of the container load, and the middle of the container load. The test load for each container consisted of four Multiple Launch Rocket System (MLRS) pods stacked two high and two wide (see part 6). In every case except the SeaVent container, a standard U.S. Air Force (USAF) side-opening container was used to evaluate the different solar radiation protection methods, thus, eliminating another possible variable that might effect the test data. The containers were placed in a rectangular grid with sufficient spacing between containers to prevent one container from shading another container at any point during the day. The weather station was programmed to sample the ambient gages every 15 seconds, sample the external thermocouples every minute, and output an average value to a solid-state storage module every 15 minutes. The solid-state storage module was downloaded onto a computer on a weekly basis where the environmental data could be analyzed. The testing sequence for the evaluation of the container protection methods is as shown in Table 1.

Table 1: Sequence of Test Events.

Item Evaluated	Evaluation Dates
FIT Ceramic Coating No. 1	19 Jun - 28 Aug 92
NRDEC Double-thickness Tarpaulin Covered Container	
Standard USAF Side-opening Container	

Item Evaluated	Evaluation Dates
FIT Ceramic Coating No. 1 Standard USAF Side-opening Container	27 Aug - 29 Oct 93
FIT Ceramic Coating No. 2 Tan-painted Container Enamel White-painted Container NRDEC Container Cover NRDEC Tarpaulin-covered Container Standard USAF Side-opening Container	03 Jun - 05 Aug 94
FIT Ceramic Coating No. 2 Tan-painted Container Enamel White-painted Container NRDEC Container Cover Worldwide Container Cover Standard USAF Side-opening Container	5 Aug - 23 Sep 94
FIT Ceramic Coating No. 2 Tan-painted Container Enamel White-painted Container NRDEC Container Cover SeaVent Container Standard USAF Side-opening Container	07 Jul - 05 Sep 95

PART 4

METHOD OF ANALYSIS

Analysis of the test data collected during the evaluation periods consisted of the following calculations: average of the daily peak readings, average of the daily peak temperature elevation over ambient, average of the daily peak temperature reduction under the control container, and frequency distributions. Results from these calculations were used to compare the effectiveness of the different solar radiation protection methods.

The average of the daily peak readings calculation was performed by taking the average of all the daily peak readings for each individual data channel. Each peak reading was chosen without regard for the time of occurrence of any other peak reading in any of the other data channels; i.e., the peak reading for one data channel may or may not occur at the same time of day as another data channel (see page 4-2, example 1). The results from this calculation show how hot the temperature was at the monitored test points.

The average daily peak temperature elevation over ambient was performed in a two-step process. The first step consisted of calculating the differential temperatures by subtracting the ambient temperature from each time corresponding temperature reading in the tested containers. The average of the daily peak differential readings was then calculated for each given data channel. As before, each peak differential value was chosen without regard for the time of occurrence of any other peak differential values (see page 4-3, example 2). The results from this calculation show the degree to which the solar radiation exposure was elevating the temperature at the monitored test points above the ambient temperature.

The average daily peak temperature reduction under the control was also performed in a two-step process. The first step consisted of calculating the differential temperatures by

subtracting the temperature readings of the control container from the corresponding temperature reading (both time and test position within the container) in the tested containers. The average daily peak differential readings was then calculated for each given data channel in the evaluated containers. As before, each peak differential value was chosen without regard for the time of occurrence of any other peak differential values (see page 4-3, example 3). The results from this calculation show how the test points in the evaluated container compared to the coresponding test point in the control container.

Frequency distributions of the temperature readings were performed based on the number of degrees the monitored test position was over the ambient temperature . The number of temperature readings greater than 10, 20, 30, 40, and 50 degrees over the ambient temperature was determined for each monitored test point.

Example 1: Daily Peak Value Determination.

Using the values in Table 2 (page 4-4), the following daily peak values would be obtained the Julian date 240.

Ambient: 72.3

Control, Exterior Top: 92.9

Control, Interior Top: 91.8

Ceramic, Exterior Top: 79.9

Ceramic, Interior Top: 77.6

Example 2: Daily Peak Temperature Elevation Over Ambient.

Using the values in Table 2 (page 4-4), the following daily peak temperature elevations over ambient would be obtained for Julian date 240. Table 3 (page 4-5) shows the results from the individual differential calculations used to select the following peak values:

Control, Exterior Top: 23.82

Control, Interior Top: 22.72

Ceramic, Exterior Top: 9.82

Ceramic, Interior Top: 6.4

Example 3: Daily Peak Temperature Reduction Under the Control Container.

Using the values in Table 2 (page 4-4), the following daily peak temperature elevations over the control container would be obtained for Julian date 240. Table 4 (page 4-6) shows the results from the individual differential calculations used to select the following peak values:

Ceramic, Exterior Top: 14

Ceramic, Interior Top: 16.8

TABLE 2

SAMPLE TEST VALUES FOR DEMONSTRATION OF CALCULATIONS

Julian Date	Time	Ambient	Control, Exterior Top	Control, Interior Top	Ceramic, Exterior Top	Ceramic, Interior Top
240	100	70.70	72.50	74.00	70.40	72.40
240	200	69.75	72.50	74.00	70.30	72.30
240	300	69.87	72.10	73.50	69.93	71.80
240	400	69.24	71.90	73.30	69.08	71.00
240	500	68.36	70.70	72.20	68.46	70.40
240	600	68.18	68.36	70.50	67.33	69.14
240	700	67.62	69.43	70.80	67.36	68.89
240	800	67.42	69.96	70.80	68.19	69.16
240	900	67.45	73.60	75.20	70.90	70.30
240	1000	68.15	77.20	76.90	70.00	69.99
240	1100	69.65	80.50	79.90	73.00	71.20
240	1200	69.08	92.90	91.80	78.90	75.00
240	1300	71.20	89.40	88.60	79.90	77.60
240	1400	72.30	80.50	81.00	76.80	77.40
240	1500	72.20	75.60	76.40	74.00	74.20
240	1600	72.30	75.90	76.30	74.00	73.90
240	1700	71.70	74.60	75.80	71.90	72.10
240	1800	70.20	71.10	72.20	69.95	71.10
240	1900	69.00	69.82	71.00	68.64	69.99
240	2000	67.71	69.01	70.30	67.60	68.96
240	2100	67.86	67.83	69.01	66.98	68.06
240	2200	67.29	68.18	69.58	66.82	67.91
240	2300	67.07	68.48	69.68	66.67	67.60
240	2400	67.02	68.67	69.55	66.61	67.51

Note: The data have been reduced to hourly readings for this example only. All data were used during the actual data analysis.

TABLE 3

CALCULATION OF DIFFERENTIAL TEMPERATURES FOR THE AVERAGE OF THE DAILY PEAK TEMPERATURE ELEVATION OVER AMBIENT

Julian Date	Time	Control to Ambient Differential, Exterior Top	Control to Ambient Differential, Interior Top	Ceramic to Ambient Differential, Exterior Top	Ceramic to Ambient Differential, Interior Top
240	100	1.80	3.30	-0.30	1.70
240	200	2.75	4.25	0.55	2.55
240	300	2.23	3.63	0.06	1.93
240	400	2.66	4.06	-0.16	1.76
240	500	2.34	3.84	0.10	2.04
240	600	0.18	2.32	-0.85	0.96
240	700	1.81	3.18	-0.26	1.27
240	800	2.54	3.38	0.77	1.74
240	900	6.15	7.75	3.45	2.85
240	1000	9.05	8.75	1.85	1.84
240	1100	10.85	10.25	3.35	1.55
240	1200	23.82	22.72	9.82	5.92
240	1300	18.20	17.40	8.70	6.40
240	1400	8.20	8.70	4.50	5.10
240	1500	3.40	4.20	1.80	2.00
240	1600	3.60	4.00	1.70	1.60
240	1700	2.90	4.10	0.20	0.40
240	1800	0.90	2.00	-0.25	0.90
240	1900	0.82	2.00	-0.36	0.99
240	2000	1.30	2.59	-0.11	1.25
240	2100	-0.03	1.15	-0.88	0.20
240	2200	0.89	2.29	-0.47	0.62
240	2300	1.41	2.61	-0.40	0.53
240	2400	1.65	2.53	-0.41	0.49

Note: The data have been reduced to hourly readings for this example only. All data were used during the actual data analysis.

TABLE 4

CALCULATION OF DIFFERENTIAL TEMPERATURES FOR THE AVERAGE OF THE DAILY PEAK TEMPERATURE REDUCTION UNDER THE CONTROL CONTAINER

Julian Date	Time	Control to Ceramic Differential, Exterior Top	Control to Ceramic Differential, Interior Top
240	100	2.10	1.60
240	200	2.20	1.70
240	300	2.17	1.70
240	400	2.82	2.30
240	500	2.24	1.80
240	600	1.03	1.36
240	700	2.07	1.91
240	800	1.77	1.64
240	900	2.70	4.90
240	1000	7.20	6.91
240	1100	7.50	8.70
240	1200	14.00	16.80
240	1300	9.50	11.00
240	1400	3.70	3.60
240	1500	1.60	2.20
240	1600	1.90	2.40
240	1700	2.70	3.70
240	1800	1.15	1.10
240	1900	1.18	1.01
240	2000	1.41	1.34
240	2100	0.85	0.95
240	2200	1.36	1.67
240	2300	1.81	2.08
240	2400	2.06	2.04

Note: The data have been reduced to hourly readings for this example only. All data were used during the actual data analysis.

PART 5

TEST RESULTS

The first phase of testing during the summer months of 1992 consisted of a comparison of the first ceramic coating formula from FIT; NRDEC double-thickness tarpaulin; and a standard-colored USAF side-opening container. Results from the summer months of 1992 indicated that the ceramic coating from FIT was providing minimal protection from the temperature elevating effects of the solar radiation while the NRDEC double-thickness tarpaulin almost totally eliminated any temperature elevation from the solar radiation exposure (see tables 5 - 7). As seen in tables 5 - 7, the NRDEC cover had a lower average daily peak reading than the ceramic-coated container, was within approximately 10 degrees of ambient at all monitored points within the container, and had peak differential temperature readings that were significantly lower (as compared to the control container) than the ceramic-coated container. In table 8, the frequency distributions of the collected test data show that the ceramic-coated container had approximately the same number of elevated temperature readings as did the control container while the NRDEC tarpaulin-covered container had no readings more than 20 degrees above ambient and approximately 1,000 readings or less at the monitored test points.

TABLE 5

AVERAGE DAILY PEAK READINGS (19 Jun - 28 Aug 92)

	Control	NRDEC Cover	Ceramic
Exterior Top	115.96	80.89	118.18
Interior Top	119.34	81.48	118.59
6" Down from Top	107.48	84.30	110.53
Top of Load	97.28	82.06	96.06
Middle of Load	83.35	77.40	85.59
Ambient Temp	77.82		
Solar	396.72		

Note: All temperatures in degrees Fahrenheit. Solar radiation in BTU/(hr-ft-ft).

TABLE 6

AVERAGE DAILY PEAK TEMPERATURE ELEVATION OVER THE AMBIENT TEMPERATURE (19 Jun - 28 Aug 92)

	Control	NRDEC Cover	Ceramic
Exterior Top	44.16	6.21	46.28
Interior Top	47.29	7.34	46.58
6" Down from Top	35.23	9.75	38.47
Top of Load	23.81	10.01	22.40
Middle of Load	14.30	11.13	13.66

Note: All temperatures in degrees Fahrenheit.

TABLE 7

AVERAGE DAILY PEAK TEMPERATURE REDUCTION UNDER THE CONTROL CONTAINER (19 Jun - 28 Aug 92)

	NRDEC Cover	Ceramic
Exterior Top	38.72	3.47
Interior Top	41.12	5.12
6" Down from Top	27.95	1.63
Top of Load	19.75	2.40
Middle of Load	6.45	1.89

Note: All temperatures in degrees Fahrenheit.

TABLE 8
FREQUENCY DISTRIBUTIONS FOR THE TEST DATA COLLECTED
19 Jun - 28 Aug 92

	Exterior Top	Interior Top	6" Below Top	Top of Load	Middle of Load	Range
Control	2579	2697	3768	3828	2042	>10
	1931	2021	2009	1225	2	>20
	1298	1470	1119	69	0	>30
	648	847	175	0	0	>40
	161	282	0	0	0	>50
NRDEC Tarp	0	19	638	698	1009	>10
	0	0	0	0	0	>20
	0	0	0	0	0	>30
	0	0	0	0	0	>40
	0	0	0	0	0	>50
Ceramic	2576	2639	4178	4784	2180	>10
	1987	2027	2095	1081	0	>20
	1441	1500	1316	41	0	>30
	828	867	489	0	0	>40
	308	338	28	0	0	>50

During the summer months of 1993, the first ceramic coating formula from FIT was compared against a standard colored USAF side-opening container. Results from the analysis of the test data collected indicated that the ceramic coating performed better than the previous summer, however, was still providing only minimal protection from the temperature elevating effects of the solar radiation (see tables 9 - 12). As seen in tables 9 - 10, the ceramic-coated container had an average daily peak reading that was approximately within 10 degrees of the control container and was within approximately 10 degrees of the control container for the average daily peak temperature elevations over ambient. In table 12, the frequency distributions of the collected test data show that the ceramic-coated container had a lower number of elevated temperature readings as compared to the control container.

TABLE 9

AVERAGE DAILY PEAK READINGS (27 Aug - 29 Oct 93)

Location	Control	Ceramic
Exterior Top	94.50	83.89
Interior Top	92.31	81.64
6" Down from Top	87.91	78.90
Top of Load	77.47	74.43
Middle of Load	68.81	69.53
Ambient Temp	66.37	
Solar Radiation	194.79	

Note: All temperatures in degrees Fahrenheit. Solar radiation in BTU/(hr-ft-ft).

TABLE 10

AVERAGE DAILY PEAK TEMPERATURE ELEVATION OVER THE AMBIENT TEMPERATURE (27 Aug - 29 Oct 93)

Location	Control	Ceramic
Exterior Top	34.15	22.40
Interior Top	31.95	20.48
6" Down from Top	28.38	17.61
Top of Load	15.82	11.04
Middle of Load	10.61	8.26

Note: All temperatures in degrees Fahrenheit.

TABLE 11

AVERAGE DAILY PEAK TEMPERATURE REDUCTION UNDER THE CONTROL CONTAINER (27 Aug - 29 Oct 93)

Location	Ceramic
Exterior Top	13.89
Interior Top	14.33
6" Down from Top	13.23
Top of Load	8.25
Middle of Load	6.02

Note: All temperatures in degrees Fahrenheit.

TABLE 12

FREQUENCY DISTRIBUTIONS FOR THE TEST DATA COLLECTED 27 Aug - 29 Oct 93

	Exterior Top	Interior Top	6" Below Top	Top of Load	Middle of Load	Range
Control	1617	1611	2210	2129	1028	>10
	1055	1001	1034	227	0	>20
	568	477	375	0	0	>30
	198	143	30	0	0	>40
	42	11	0	0	0	>50
Ceramic	1198	1105	1218	810	270	>10
	528	455	341	23	0	>20
	108	88	2	0	0	>30
	4	0	0	0	0	>40
	0	0	0	0	0	>50

Items tested during the first part of the summer months of 1994 included the second ceramic coating formula from FIT, tan paint, enamel white paint, NRDEC double-thickness tarpaulin, and a NRDEC container cover. As during the summers months of 1992 and 1993, these items were compared against a control which was a standard-colored USAF side-opening

container. Results from this data indicate that the enamel white container, NRDEC cover, and the NRDEC tarpaulin (the NRDEC tarpaulin was blown off the container during the last 10 days of monitoring; therefore, the last 10 days of data from the NRDEC tarpaulin-covered container were excluded from the calculations) provided the best protection while the ceramic and tan containers were approximately half as effective in eliminating the temperature elevating effects of solar radiation exposure (see tables 13 - 16). As seen in tables 13 - 15, the NRDEC tarpaulin, NRDEC cover, and enamel-white container had the lowest averages from the daily peak readings, the smallest averages from the daily peak temperature elevations over ambient, and the largest averages from the daily peak temperature reduction as compared to the control container. In table 16, the frequency distributions of the collected test data show that the enamel-white paint, NRDEC cover, and NRDEC tarpaulin kept the majority of the readings within 10 degrees of the ambient temperature while the ceramic coating and tan paint had a substantial number of readings over 20 and 30 degrees above the ambient temperature.

TABLE 13

AVERAGE OF THE DAILY PEAK READINGS (03 Jun - 05 Aug 94)

(Note: The last 10 days of data from the NRDEC tarpaulin were invalid.)

Location	Control	Ceramic	Tan	White	NRDEC Cover	NRDEC Tarpaulin
Exterior Top	129.79	113.86	113.03	98.13	92.57	86.46
Interior Top	127.75	114.13	109.05	90.23	91.06	88.01
6" Down from Top	115.14	106.35	101.79	88.53	89.31	89.93
Top of Load	102.27	98.72	92.03	82.81	83.91	87.08
Middle of Load	89.20	89.80	84.06	80.30	79.67	82.80
Ambient Temp	82.78					
Solar Radiation	275.51					

Note: All temperatures in degrees Fahrenheit. Solar radiation in BTU/(hr-ft-ft).

TABLE 14

AVERAGE DAILY PEAK TEMPERATURE ELEVATION OVER THE AMBIENT TEMPERATURE (03 Jun - 05 Aug 94)

(Note: The last 10 days of data from the NRDEC tarpaulin were invalid.)

Location	Control	Ceramic	Tan	White	NRDEC Cover	NRDEC Tarpaulin
Exterior Top	51.26	34.63	34.24	18.58	13.18	6.71
Interior Top	49.14	35.07	30.15	10.87	11.65	9.00
6" Down from Top	36.41	26.75	22.85	8.92	10.22	11.17
Top of Load	22.54	18.65	12.44	7.00	7.37	9.18
Middle of Load	13.49	12.05	11.24	6.99	8.53	10.26

Note: All temperatures in degrees Fahrenheit.

TABLE 15

AVERAGE DAILY PEAK TEMPERATURE REDUCTION UNDER THE CONTROL CONTAINER (03 Jun - 05 Aug 94)

(Note: The last 10 days of data from the NRDEC tarpaulin were invalid.)

Location	Ceramic	Tan	White	NRDEC Cover	NRDEC Tarp
Exterior Top	19.89	17.86	33.42	39.04	45.86
Interior Top	19.33	19.72	38.60	38.68	41.35
6" Down from Top	14.30	14.27	27.95	28.34	26.75
Top of Load	9.11	10.85	21.59	21.12	17.70
Middle of Load	7.77	7.15	9.68	12.12	8.57

Note: All temperatures in degrees Fahrenheit.

TABLE 16

FREQUENCY DISTRIBUTIONS FOR THE TEST DATA COLLECTED

03 Jun - 05 Aug 94

(Note: The last 10 days of data from the NRDEC tarpaulin were invalid.)

	Exterior Top	Interior Top	6" Below Top	Top of Load	Middle of Load	Range
Control	3077	3121	4545	5145	2125	>10
	2360	2350	2285	1096	0	>20
	1720	1684	1301	2	0	>30
	1126	1049	221	0	0	>40
	427	342	0	0	0	>50
Ceramic	2490	2448	2663	2605	738	>10
	1584	1603	1448	407	6	>20
	756	841	235	0	0	>30
	127	164	0	0	0	>40
	0	0	0	0	0	>50
Tan	2559	2415	2583	1640	1002	>10
	1630	1417	926	0	0	>20
	709	343	1	0	0	>30
	89	2	0	0	0	>40
	0	0	0	0	0	>50
White	1561	383	84	63	69	>10
	118	0	0	0	0	>20
	0	0	0	0	0	>30
	0	0	0	0	0	>40
	0	0	0	0	0	>50
NRDEC Cover	926	724	518	138	345	>10
	17	1	0	0	0	>20
	0	0	0	0	0	>30
	0	0	0	0	0	>40
	0	0	0	0	0	>50
NRDEC Tarp	26	142	531	223	502	>10
	5	9	2	0	0	>20
	0	0	0	0	0	>30
	0	0	0	0	0	>40
	0	0	0	0	0	>50

Items tested during the second part of the summer months of 1994 included the second ceramic coating formula from FIT, tan paint, enamel-white paint, NRDEC container cover, and a Fit's-Right Canvas and Supply container cover. As during the summer months of 1992 and 1993, these items were compared against a control which was a standard-colored USAF side-opening container. Results from this data indicate that the enamel-white container and NRDEC cover provided the best protection amongst the five evaluated methods. The ceramic coating, tan paint, and the Fit's-Right Canvas and Supply cover were approximately half as effective as the enamel-white container and NRDEC cover in eliminating the temperature elevating effects of solar radiation exposure (see tables 17 - 20). As seen in tables 17 - 19, the NRDEC cover and enamel-white container had the lowest averages from the daily peak readings, the smallest averages from the daily peak temperature elevations over ambient, and the largest averages from the daily peak temperature reduction as compared to the control container. In table 20, the frequency distributions of the collected test data show that the enamel-white paint and NRDEC cover maintained the majority of the readings within 10 degrees of the ambient temperature while the ceramic coating, tan paint, and Fit's-Right Canvas and Supply container cover had a substantial number of readings over 20 and 30 degrees above the ambient temperature.

TABLE 17

AVERAGE DAILY PEAK READINGS (05 Aug - 23 Sep 94)

Location	Control	Ceramic	Tan	White	NRDEC Cover	Worldwide Cover
Exterior Top	115.40	101.63	101.94	87.90	86.42	102.56
Interior Top	113.82	100.95	97.93	81.61	85.11	98.26
6" Down from Top	104.94	95.77	92.69	80.83	83.53	94.52
Top of Load	92.97	89.34	84.14	76.03	78.09	87.41
Middle of Load	81.37	81.20	77.10	73.82	73.64	77.93
Ambient Temp	77.60					
Solar Radiation	227.05					

Note: All temperatures in degrees Fahrenheit. Solar radiation in BTU/(hr-ft-ft).

TABLE 18

AVERAGE DAILY PEAK TEMPERATURE ELEVATION OVER THE AMBIENT TEMPERATURE (05 Aug - 23 Sep 94)

Location	Control	Ceramic	Tan	White	NRDEC Cover	Worldwide Cover
Exterior Top	43.09	28.34	29.32	14.52	13.14	29.89
Interior Top	41.46	27.99	25.31	8.12	11.68	25.49
6" Down from Top	32.68	22.58	20.14	7.23	9.94	21.50
Top of Load	18.94	14.77	9.91	5.72	6.45	13.14
Middle of Load	11.57	9.00	10.11	5.94	7.89	11.78

Note: All temperatures in degrees Fahrenheit.

TABLE 19

AVERAGE DAILY PEAK TEMPERATURE REDUCTION UNDER THE CONTROL CONTAINER (05 Aug - 23 Sep 94)

Location	Ceramic	Tan	White	NRDEC Cover	Worldwide Cover
Exterior Top	16.67	14.45	29.27	30.60	14.28
Interior Top	16.48	16.66	33.67	30.58	17.30
6" Down from Top	13.22	12.97	25.90	24.73	12.90
Top of Load	8.39	9.70	19.44	17.76	7.96
Middle of Load	6.71	5.97	8.22	10.13	5.73

Note: All temperatures in degrees Fahrenheit.

TABLE 20

FREQUENCY DISTRIBUTIONS FOR THE TEST DATA COLLECTED

05 Aug - 23 Sep 94

	Exterior Top	Interior Top	6" Below Top	Top of Load	Middle of Load	Range
Control	898	909	1270	1535	659	>10
	674	675	657	150	0	>20
	462	444	320	0	0	>30
	227	187	40	0	0	>40
	54	26	0	0	0	>50
Ceramic	743	716	757	622	148	>10
	459	452	366	35	0	>20
	159	166	34	0	0	>30
	12	10	0	0	0	>40
	0	0	0	0	0	>50
Tan	743	682	734	239	393	>10
	442	338	189	0	0	>20
	111	30	0	0	0	>30
	4	0	0	0	0	>40
	0	0	0	0	0	>50
White	330	22	3	23	33	>10
	4	0	0	0	0	>20
	0	0	0	0	0	>30
	0	0	0	0	0	>40
	0	0	0	0	0	>50
NRDEC Cover	320	232	154	41	158	>10
	7	1	0	0	0	>20
	0	0	0	0	0	>30
	0	0	0	0	0	>40
	0	0	0	0	0	>50
Worldwide Cover	782	763	1085	815	582	>10
	523	451	350	7	0	>20
	232	122	29	0	0	>30
	27	1	0	0	0	>40
	1	0	0	0	0	>50

Items tested during the summer months of 1995 included the second ceramic coating formula from FIT, tan paint, enamel-white paint, NRDEC container cover, and a SeaVent container. (Due to the fact that the SeaVent container was an end-opening container, a load and roll pallet (LRP) was used to store the MLRS pods in the container. The LRP is approximately 8-inches high and will cause the temperature readings from the load to be slightly higher due to the closer proximity of the temperature probes with the roof of the container as compared to the other containers.) As during previous summers, these items were compared against a control which was a standard-colored USAF side-opening container. Results from this data indicate that the enamel-white container and NRDEC cover provided the best protection amongst the five evaluated methods. The SeaVent container provided the next best protection being approximately 10 degrees higher than the enamel-white paint and NRDEC cover. The ceramic coating and tan paint were approximately half as effective as the enamel-white container and NRDEC cover in eliminating the temperature elevating effects of solar radiation exposure (see tables 21 - 24). As seen in tables 21 - 23, the NRDEC cover and U.S. Navy (USN) white container had the lowest averages from the daily peak readings, the smallest averages from the daily peak temperature elevations over ambient, and the largest averages from the daily peak temperature reduction as compared to the control container. In table 24, the frequency distributions of the collected test data show that the enamel-white paint and NRDEC cover kept the majority of the readings within 10 degrees of the ambient temperature. The SeaVent container had similar readings with the tan-painted container and ceramic-coated container for the exterior top and interior top probes, however, had lower temperature readings for the probes at 6 inches below the top, top of load, and middle of the load.

TABLE 21

AVERAGE DAILY PEAK READINGS (07 Jul - 05 Sep 95)

Location	Control	Ceramic	Tan	White	NRDEC Cover	SeaVent
Exterior Top	135.04	121.08	118.30	103.04	102.82	114.66
Interior Top	132.19	124.28	114.35	95.47	100.88	116.10
6" Down from Top	120.61	114.93	107.62	94.13	99.19	104.70
Top of Load	107.82	106.71	97.83	88.46	92.74	101.65
Middle of Load	94.59	95.71	89.39	85.84	86.62	93.58
Ambient Temp	87.97					
Solar	269.54					

Note: All temperatures in degrees Fahrenheit. Solar radiation in BTU/(hr-ft-ft).

TABLE 22

AVERAGE DAILY PEAK TEMPERATURE ELEVATION OVER THE AMBIENT TEMPERATURE (07 Jul - 05 Sep 95)

Location	Control	Ceramic	Tan	White	NRDEC Cover	SeaVent
Exterior Top	52.19	37.74	35.18	18.99	19.24	31.60
Interior Top	49.33	41.20	31.23	11.55	17.17	32.99
6" Down from Top	37.58	31.16	24.44	9.80	15.20	21.71
Top of Load	23.06	21.81	12.95	6.95	8.80	17.25
Middle of Load	13.34	12.17	11.49	6.84	9.681	2.91

Note: All temperatures in degrees Fahrenheit.

TABLE 23

AVERAGE DAILY PEAK TEMPERATURE REDUCTION UNDER THE CONTROL CONTAINER (07 Jul - 05 Sep 95)

Location	Control	Ceramic	Tan	White	NRDEC Cover	SeaVent
Exterior Top	52.19	37.74	35.18	18.99	19.24	31.60
Interior Top	49.33	41.20	31.23	11.55	17.17	32.99
6" Down from Top	37.58	31.16	24.44	9.80	15.20	21.71
Top of Load	23.06	21.81	12.95	6.95	8.80	17.25
Middle of Load	13.34	12.17	11.49	6.84	9.68	12.91

Note: All temperatures in degrees Fahrenheit.

TABLE 24

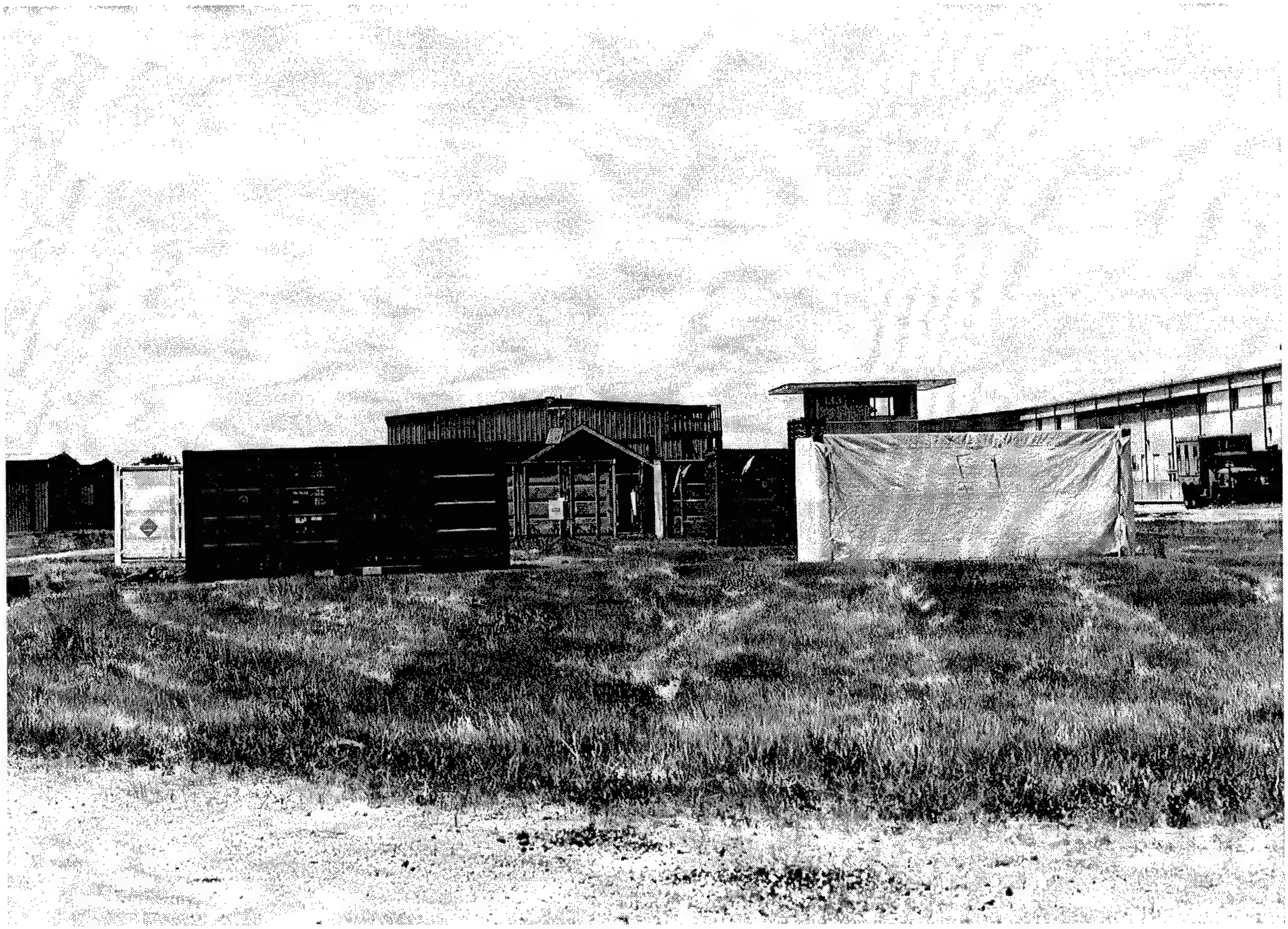
FREQUENCY DISTRIBUTIONS FOR THE TEST DATA COLLECTED 07 Jul - 05 Sep 95

	Exterior Top	Interior Top	6" Below Top	Top of Load	Middle of Load	Range
Control	2468	2489	3666	4328	1658	>10
	1970	1956	1957	973	0	>20
	1457	1401	1105	1	0	>30
	920	803	112	0	0	>40
	309	197	0	0	0	>50
Ceramic	2136	2183	2412	2445	739	>10
	1482	1610	1514	670	0	>20
	775	1017	407	0	0	>30
	113	288	1	0	0	>40
	0	7	0	0	0	>50
Tan	2077	1977	2198	1611	909	>10
	1355	1154	860	0	0	>20
	576	307	4	0	0	>30
	42	3	0	0	0	>40
	0	0	0	0	0	>50

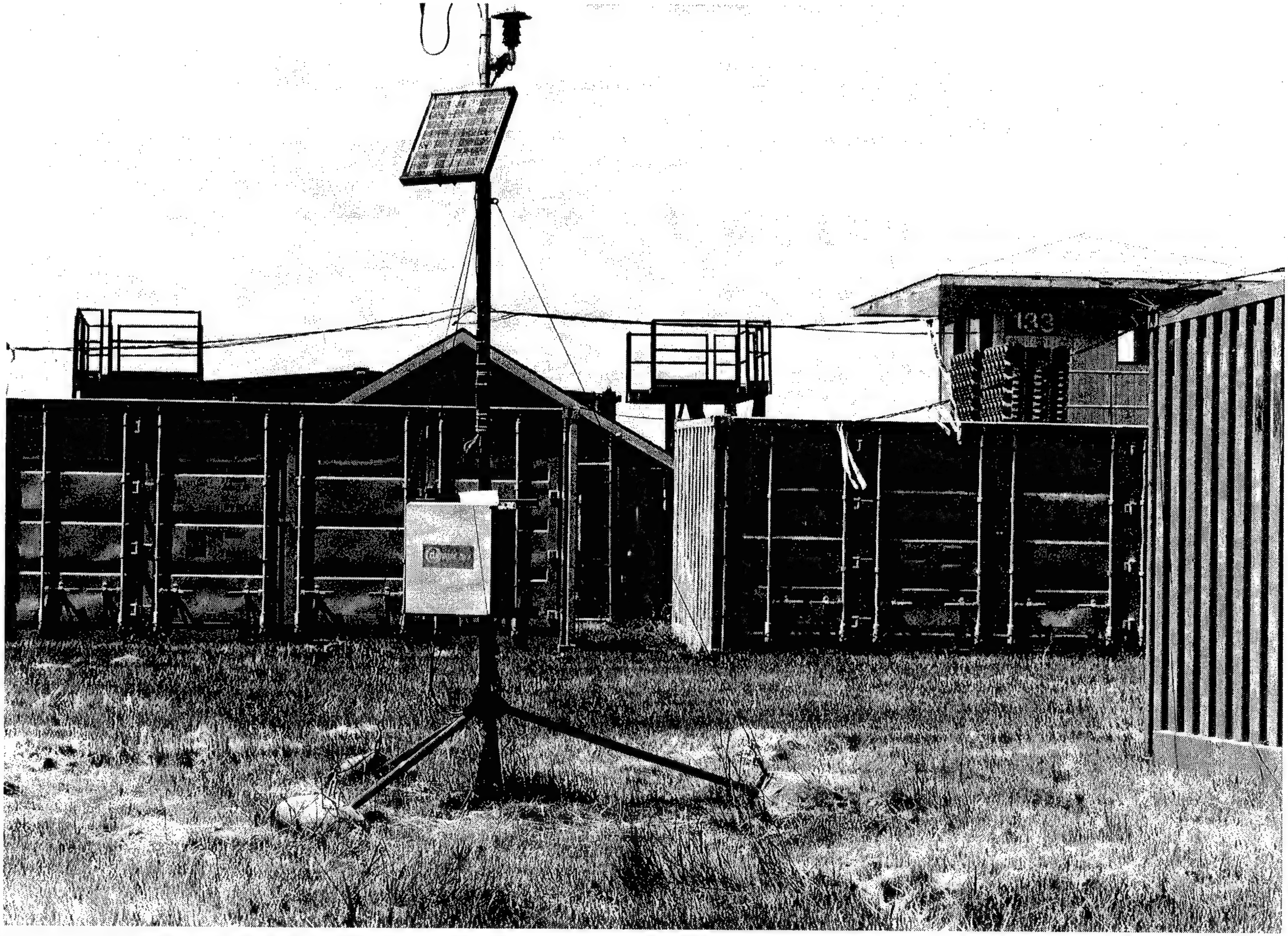
	Exterior Top	Interior Top	6" Below Top	Top of Load	Middle of Load	Range
White	1314	426	152	49	45	>10
	100	0	0	0	0	>20
	0	0	0	0	0	>30
	0	0	0	0	0	>40
	0	0	0	0	0	>50
NRDEC Cover	1402	1281	1386	279	482	>10
	142	37	3	0	0	>20
	0	0	0	0	0	>30
	0	0	0	0	0	>40
	0	0	0	0	0	>50
SeaVent	1804	1859	2783	2420	1459	>10
	1121	1187	522	168	0	>20
	562	667	0	0	0	>30
	82	151	0	0	0	>40
	0	1	0	0	0	>50

PART 6

PHOTOGRAPHS



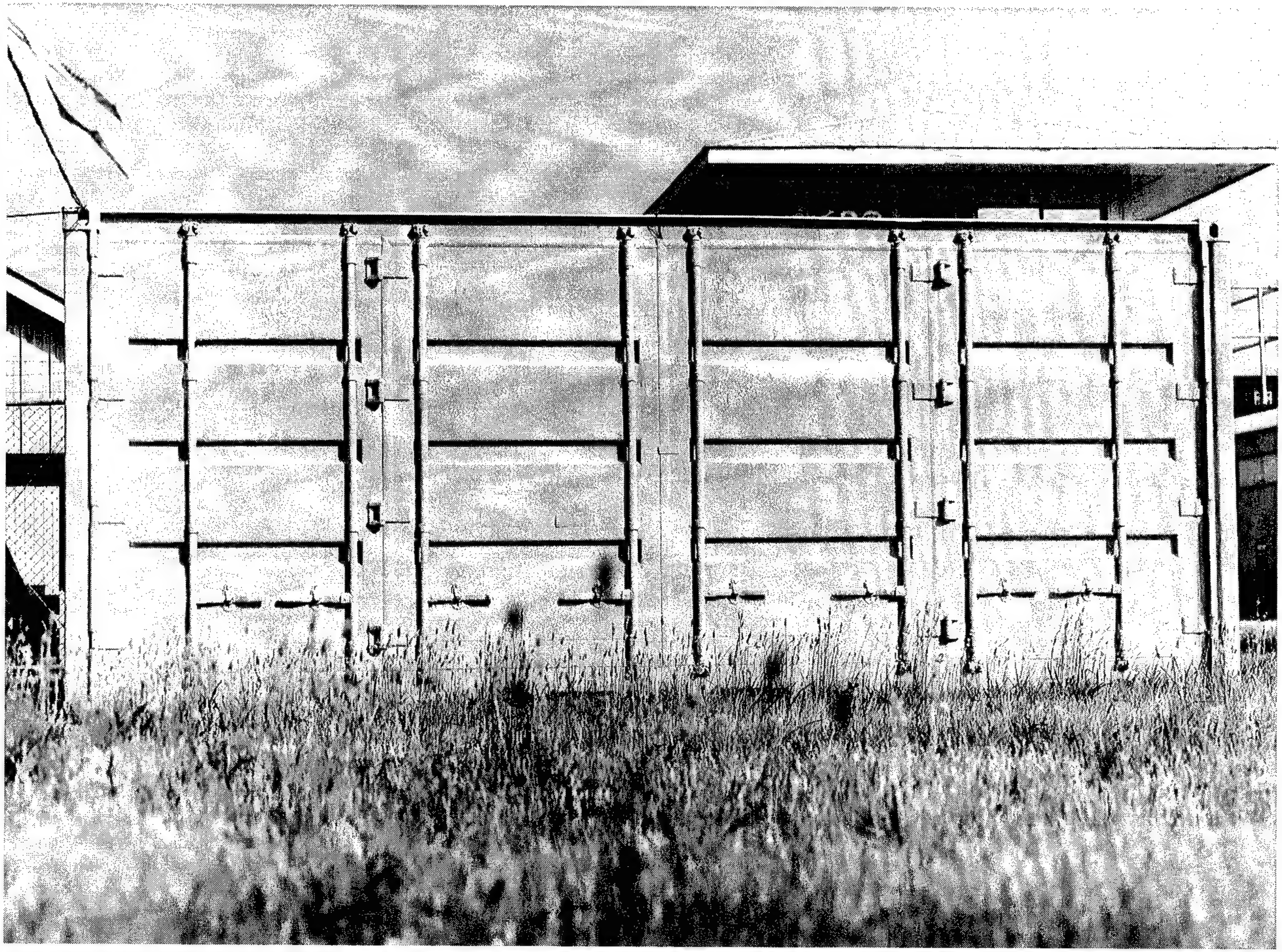
	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
AO317-SCN95-145-1767. This photograph shows the layout that was used to monitor the temperatures within the containers.		



U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL -
SAVANNA, IL

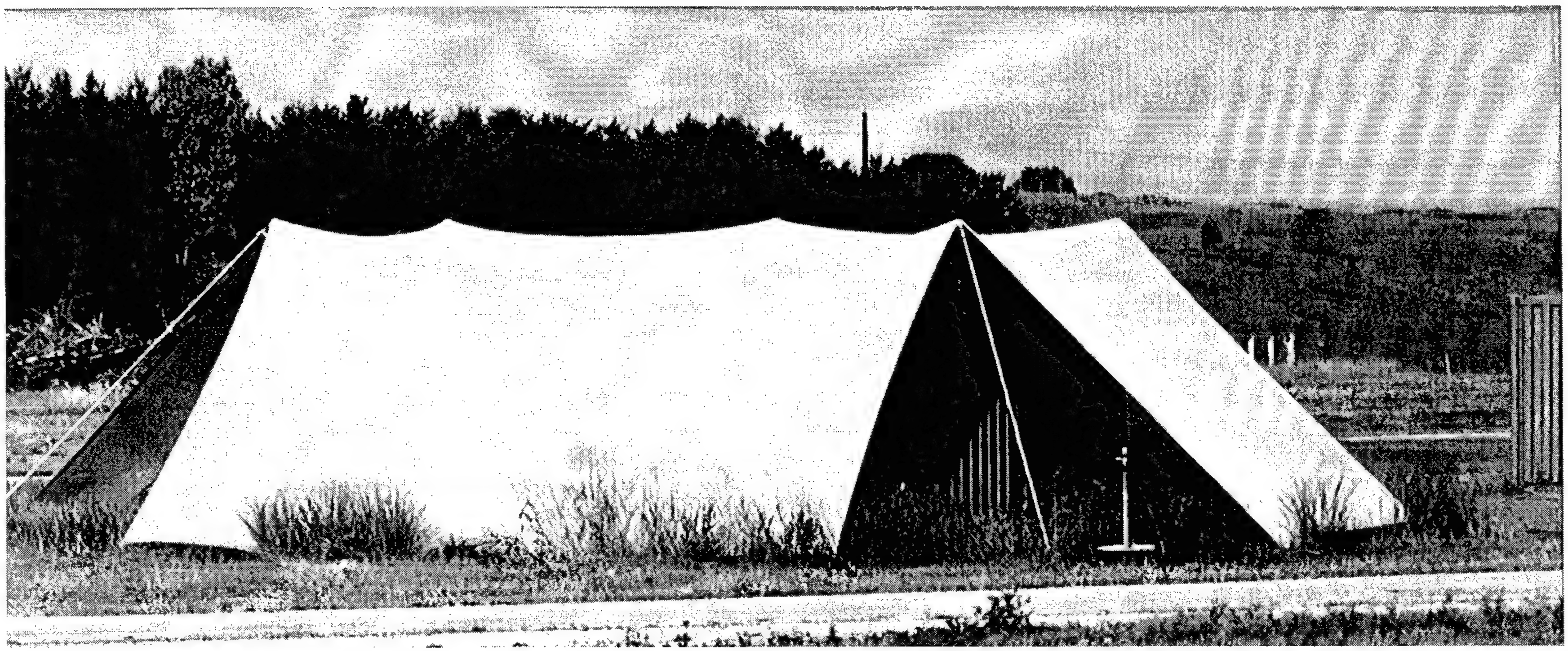
AO317-SCN95-145-1757. This photograph shows the Climatronics weather station that was used to monitor the ambient conditions and the temperatures within the containers.

	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	
AO317-SCN95-145-1760. This photograph shows a standard side-opening USAF container loaded with four MLRS pods.		



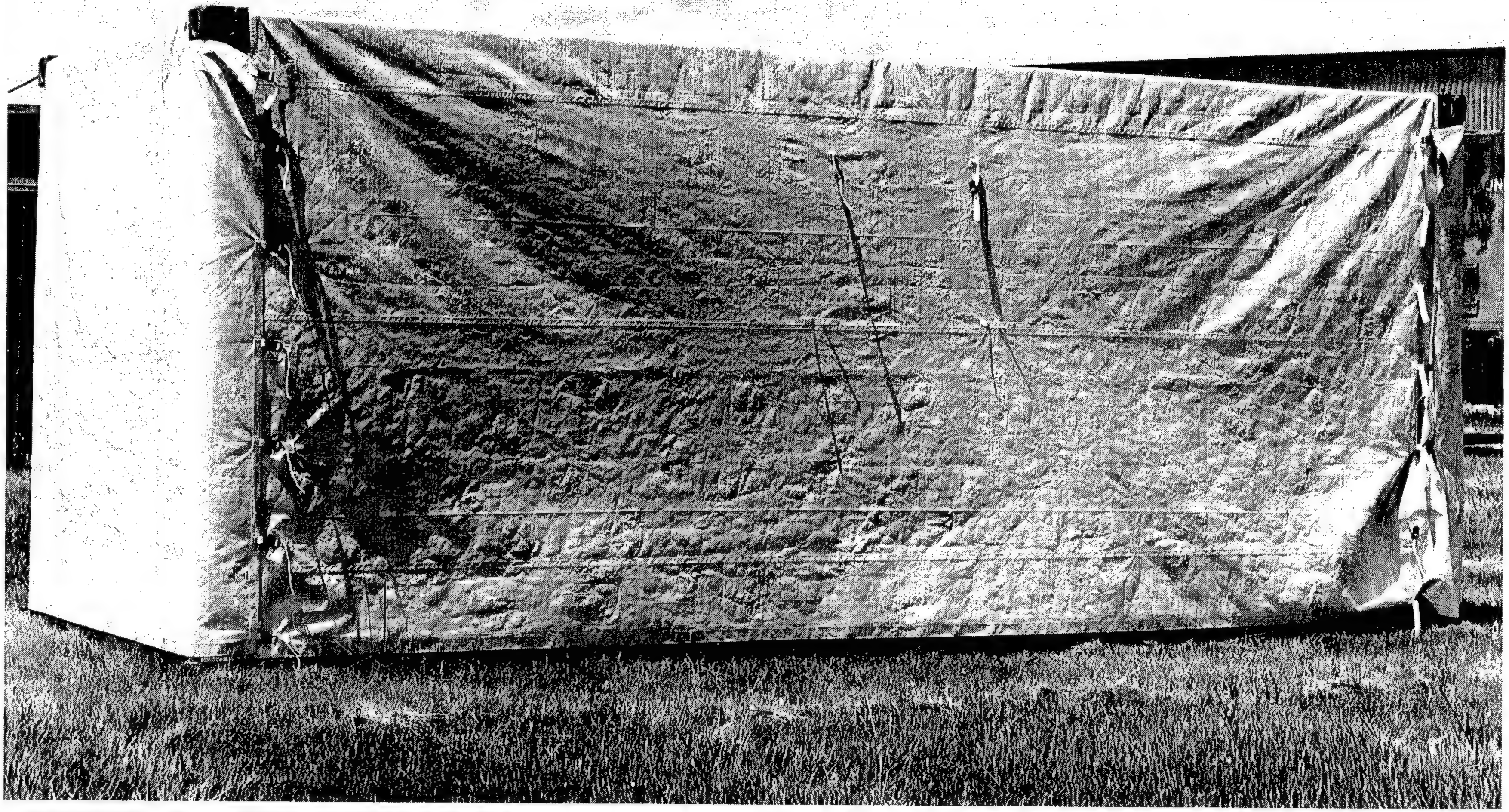
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

AO317-SCN95-145-1770. This photograph shows the second formulation of ceramic coating provided by FIT.



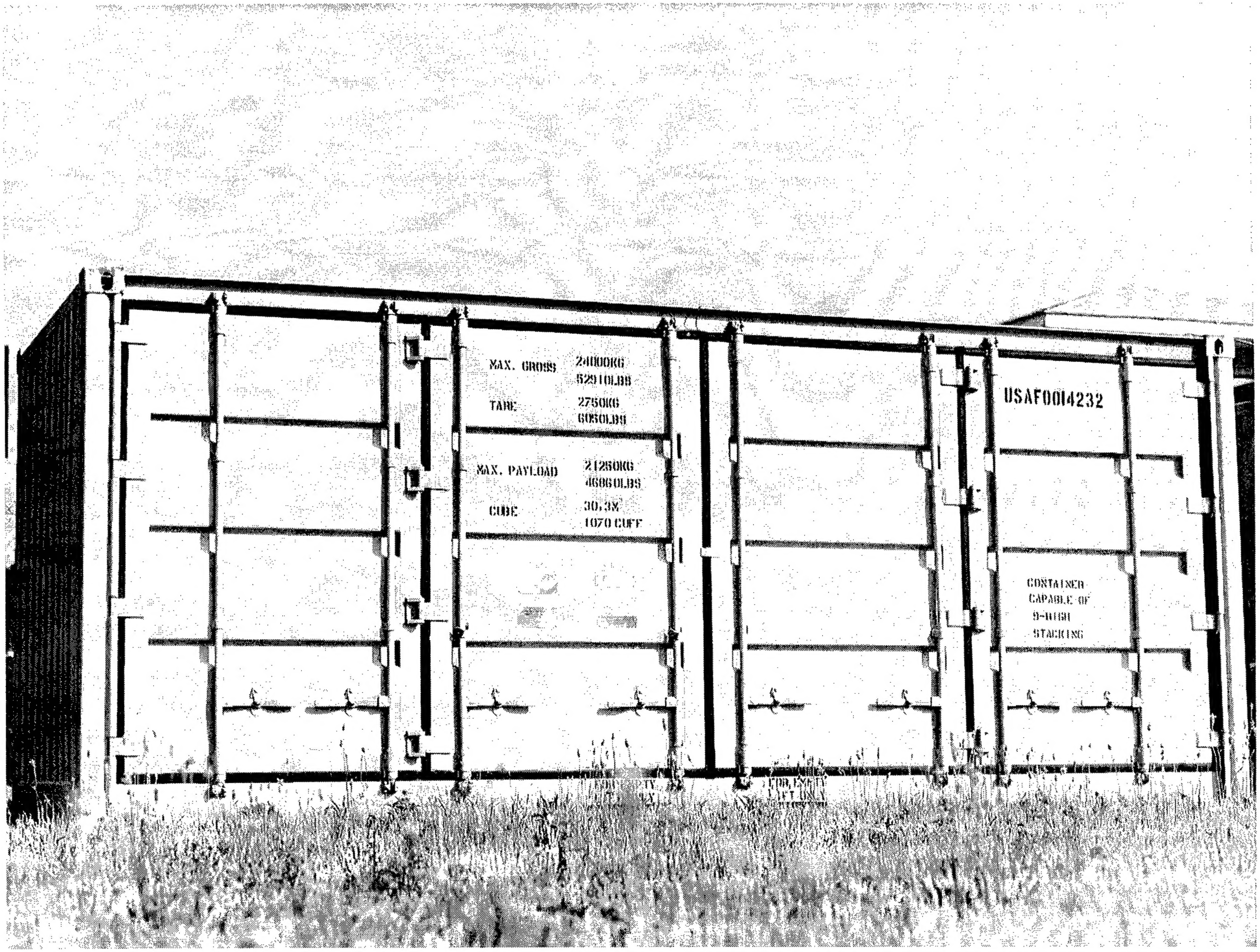
	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	

AO317-SCN95-4907-91. This photograph shows the NRDEC double-thickness tarpaulin covering a standard side-opening USAF container.



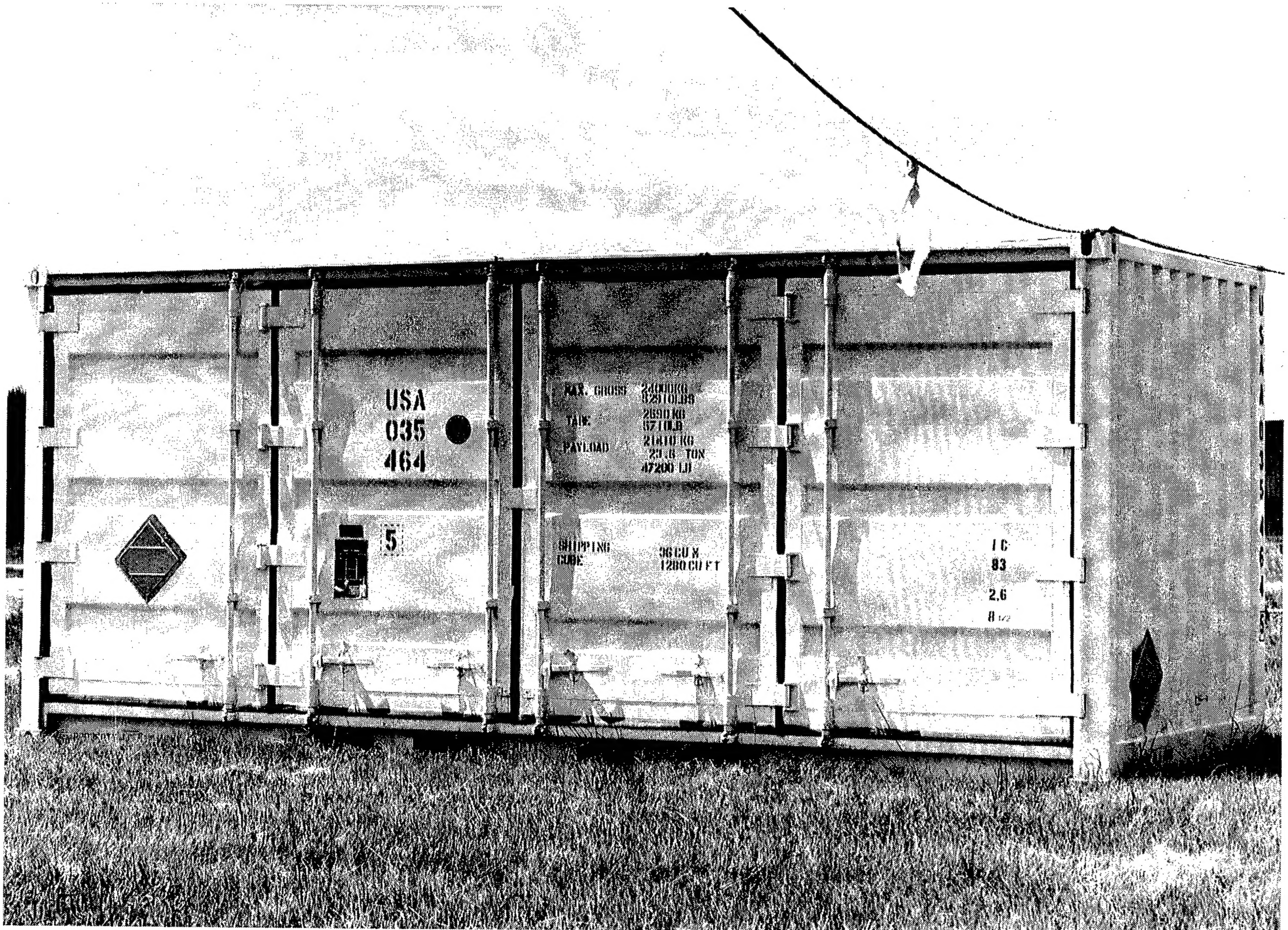
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

AO317-SCN95-145-1759. This photograph shows the NRDEC container cover.



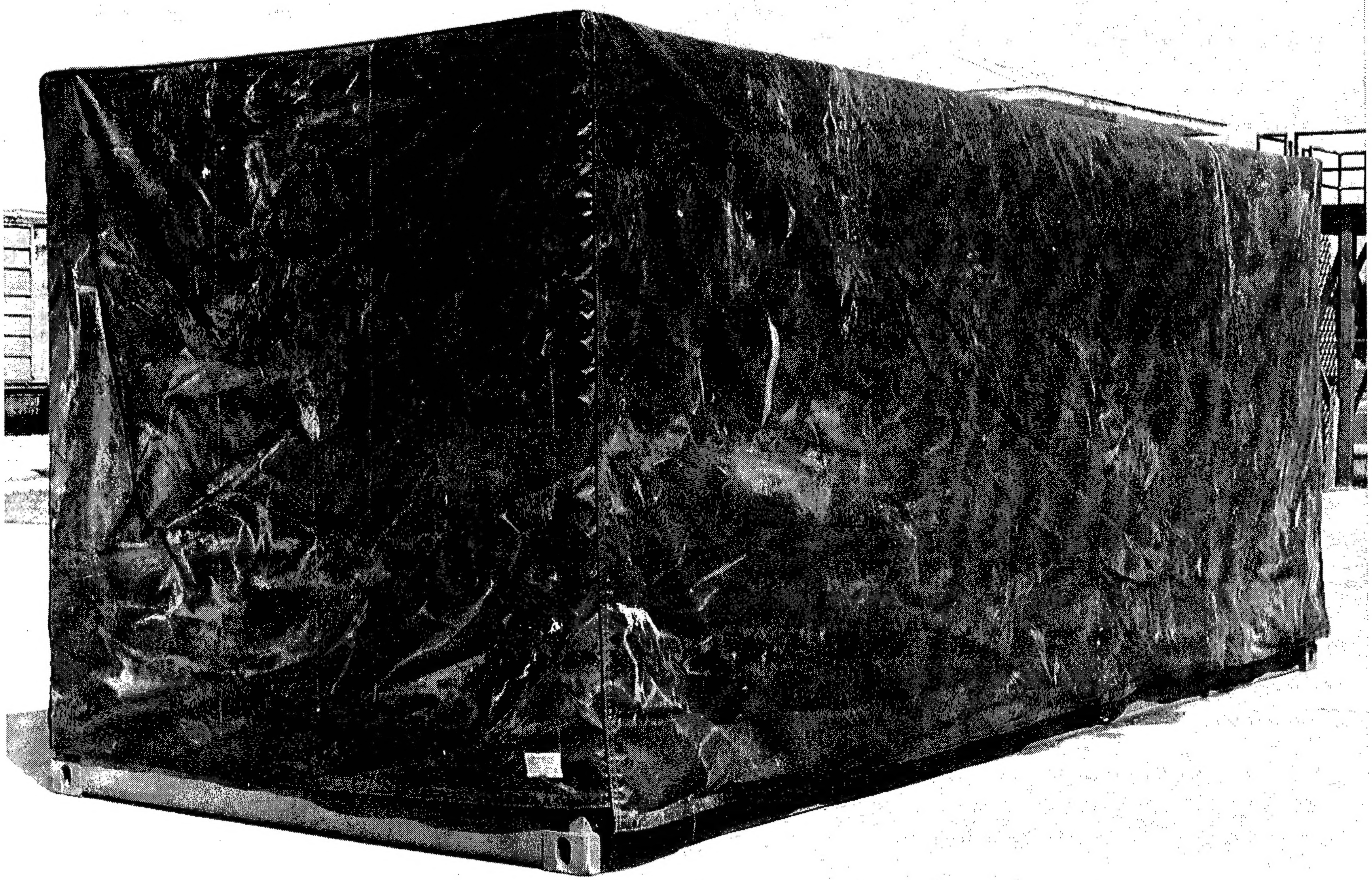
	U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL	

AO317-SCN95-145-1769. This photograph shows the tan painted side-opening container.



U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

AO317-SCN95-145-1758. This photograph shows the enamel-white painted side-opening container.



U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

AO317-SCN96-152-2771. This photograph shows the worldwide container cover.

U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

AO317-SCN95-145-1768. This photograph shows the SeaVent container.